

Air Force Power Requirements

January 24, 2006



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Power Division
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Air Force Research Laboratory**

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Outline



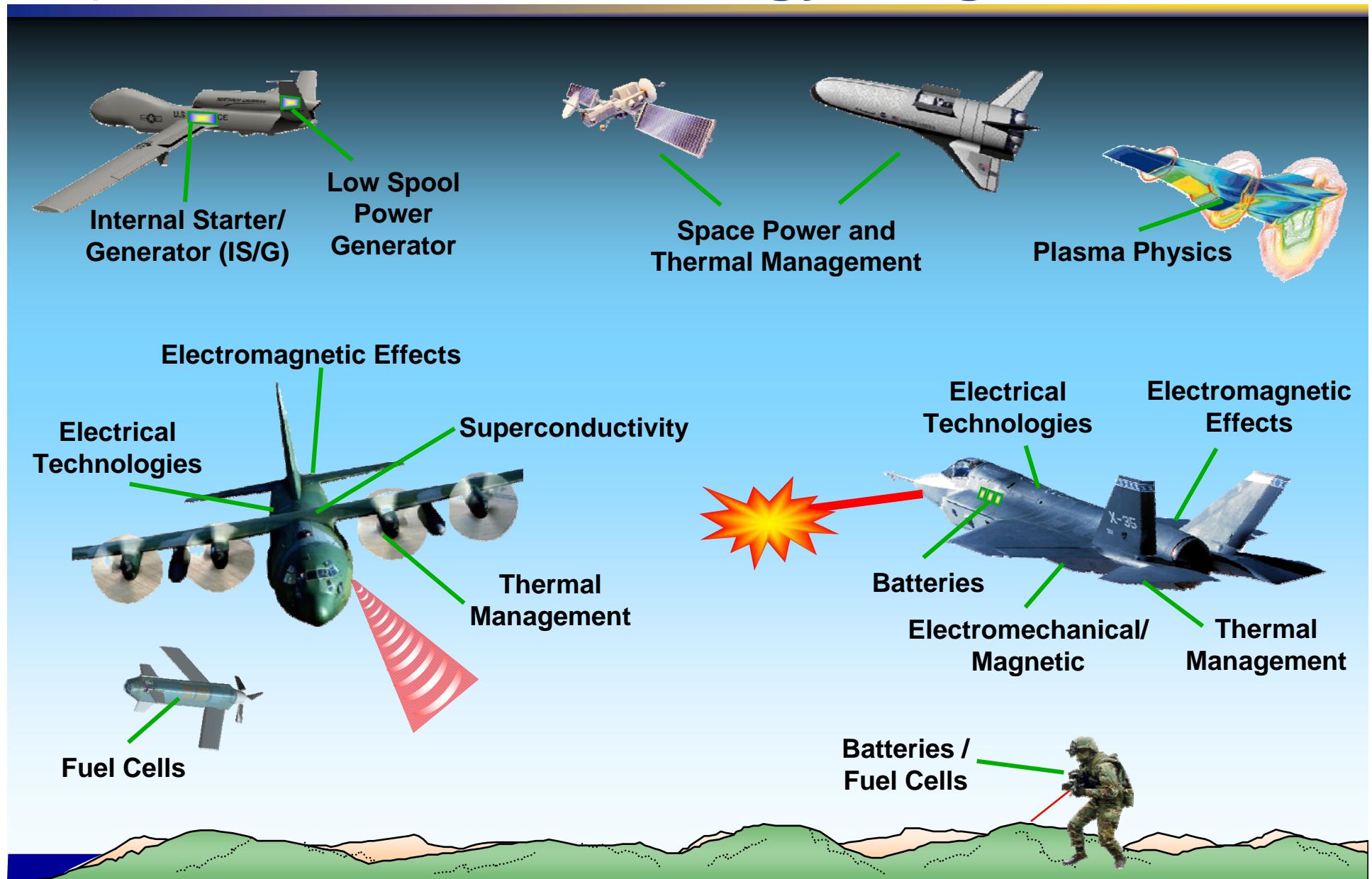
- Our Recent Heritage – MEA
- Our Plan – HiPAC
- HiPAC Technologies
- Summary



Powering the United States Air Force



Air Force Research Lab Power Technology Program





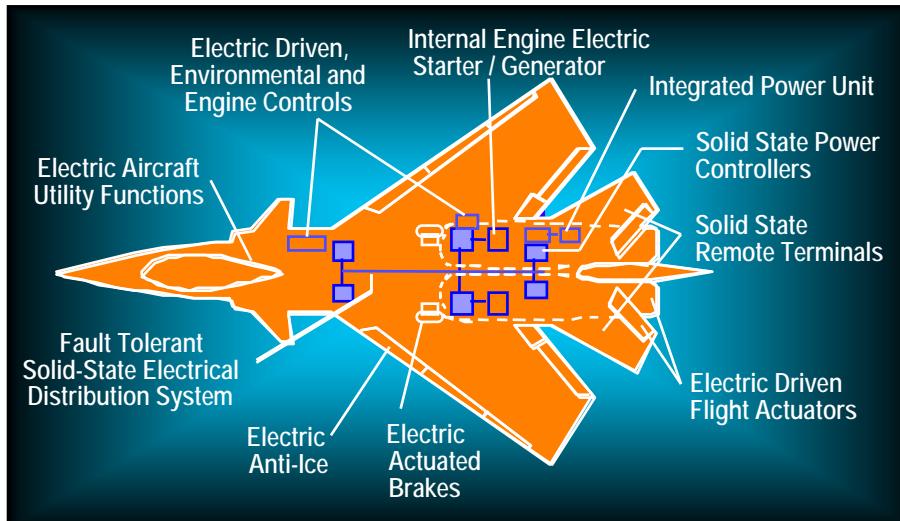
Our History: The More Electric Aircraft



THE VISION



THE IMPACT



All-electric aircraft eliminates complex, inefficient, maintenance intensive...

- Hydraulics
- Bleed Air Pneumatics
- Mechanical (gearbox) Subsystems

Savings in \$B's with improved warfighting

Enables mission available power for lethal airborne directed energy weapon



MEA Generation I Concept Transition to Lockheed F-35

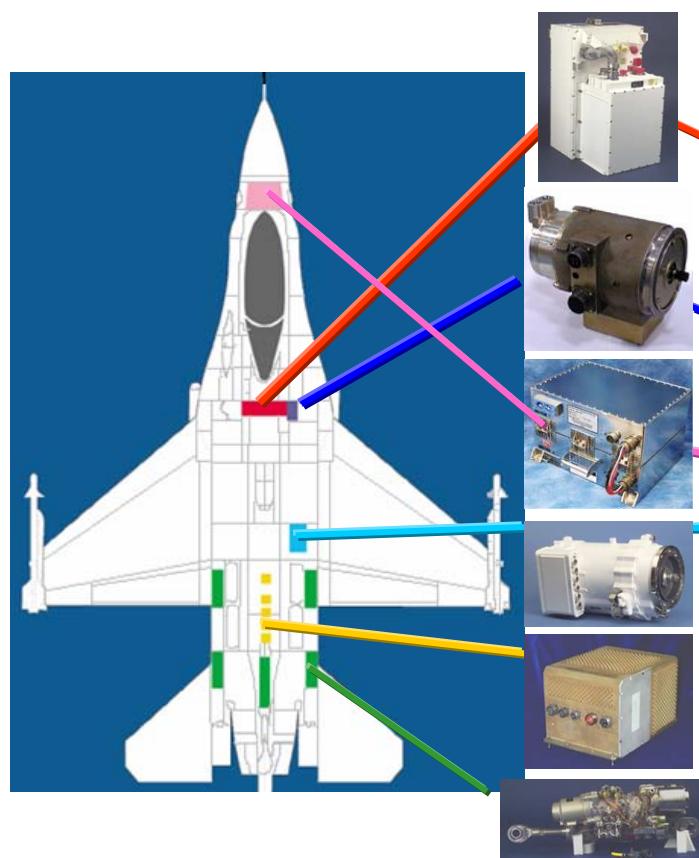


Affordable, High-Performance Baseline for F-35

*AFTI/F-16 Demonstration Validates
More-Electric Aircraft Technologies*

Common Components

*F-35 Subsystems Suite
Identical to J/IST*



Inverter/Converter/Controller (2) –
Provides Conditioned 270-VDC
Power to Flight Critical Actuation
System

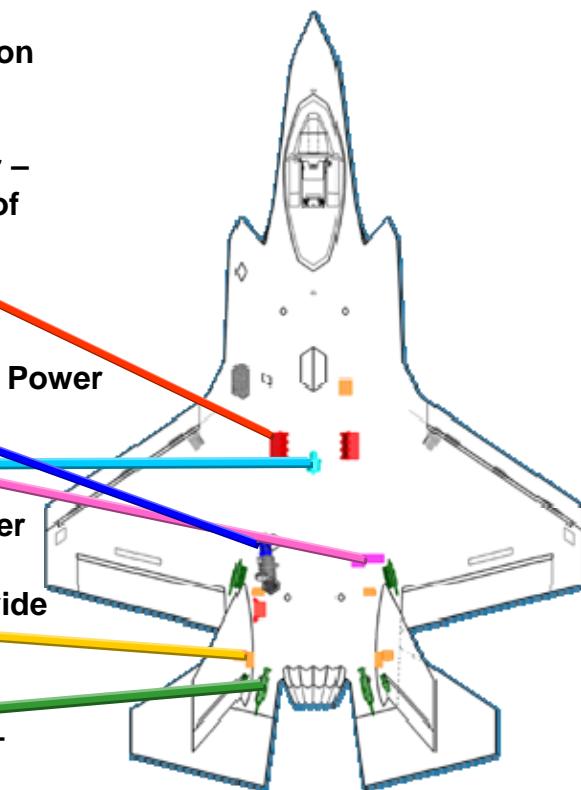
270-VDC Emergency Generator –
Provides Independent Source of
Electrical Power

270-VDC Battery – Provides
Uninterruptible, Flight-Critical Power

Starter/Generator – Source for
Redundant, Flight-Critical Power

Power Drive Electronics – Provide
Modulated 270-VDC Power to
Flight Control Actuators

Electro-hydrostatic Actuators –
Provide Redundant Control
Power at Each Control Surface





From Vision to Reality



F-35 IS THE FIRST TRULY “MORE ELECTRIC” AIRPLANE



Electric Engine Start Ground Demo

- Electric Engine Start
- Electric Power & Thermal Mgt System
- Electric Flight Control Actuation
- Electric Flight Control Power Systems



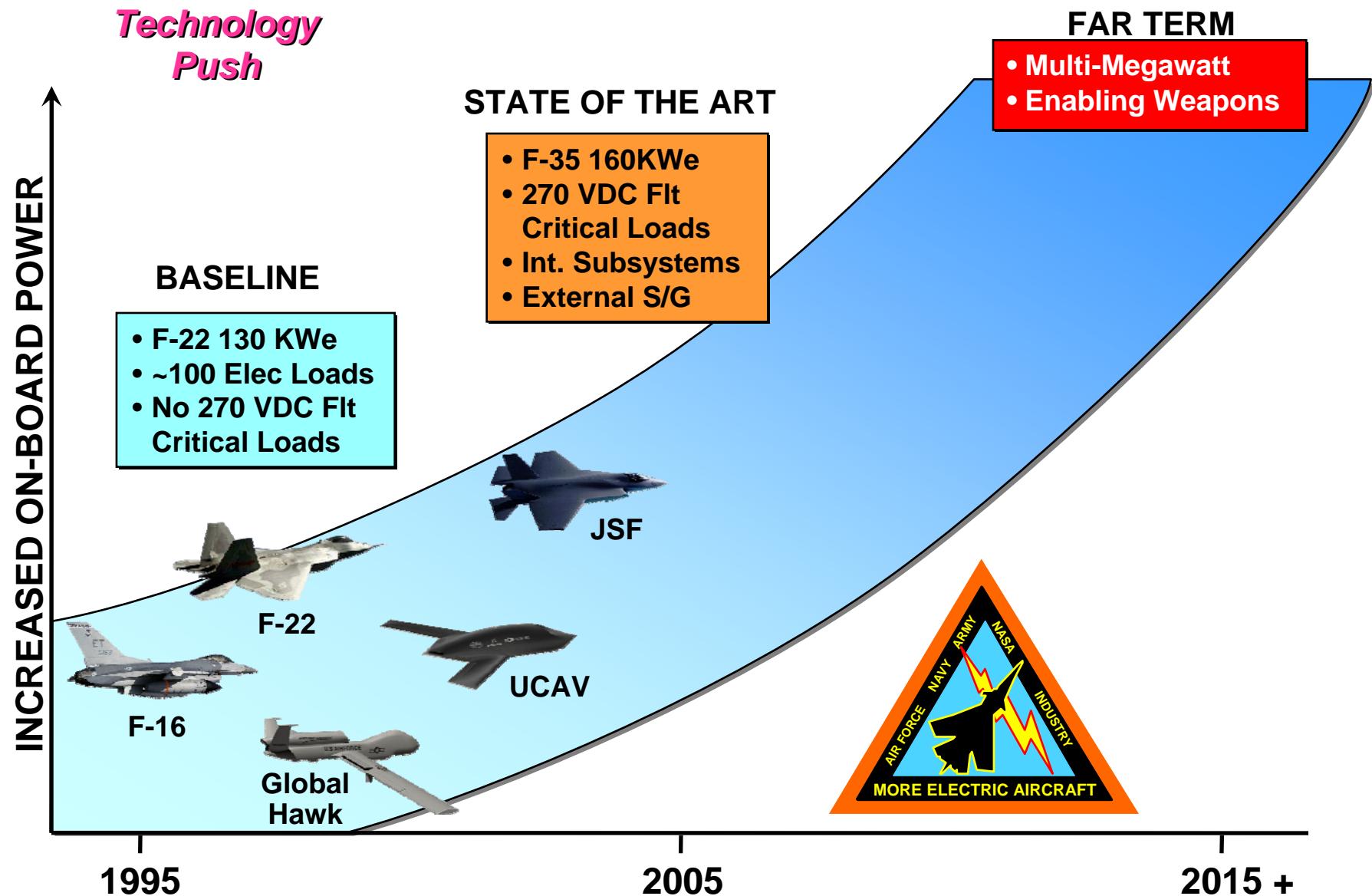
Starter/Generator / Electric Flight
Control Actuation Flight Demo



MEA Thrust Initiated In 1987

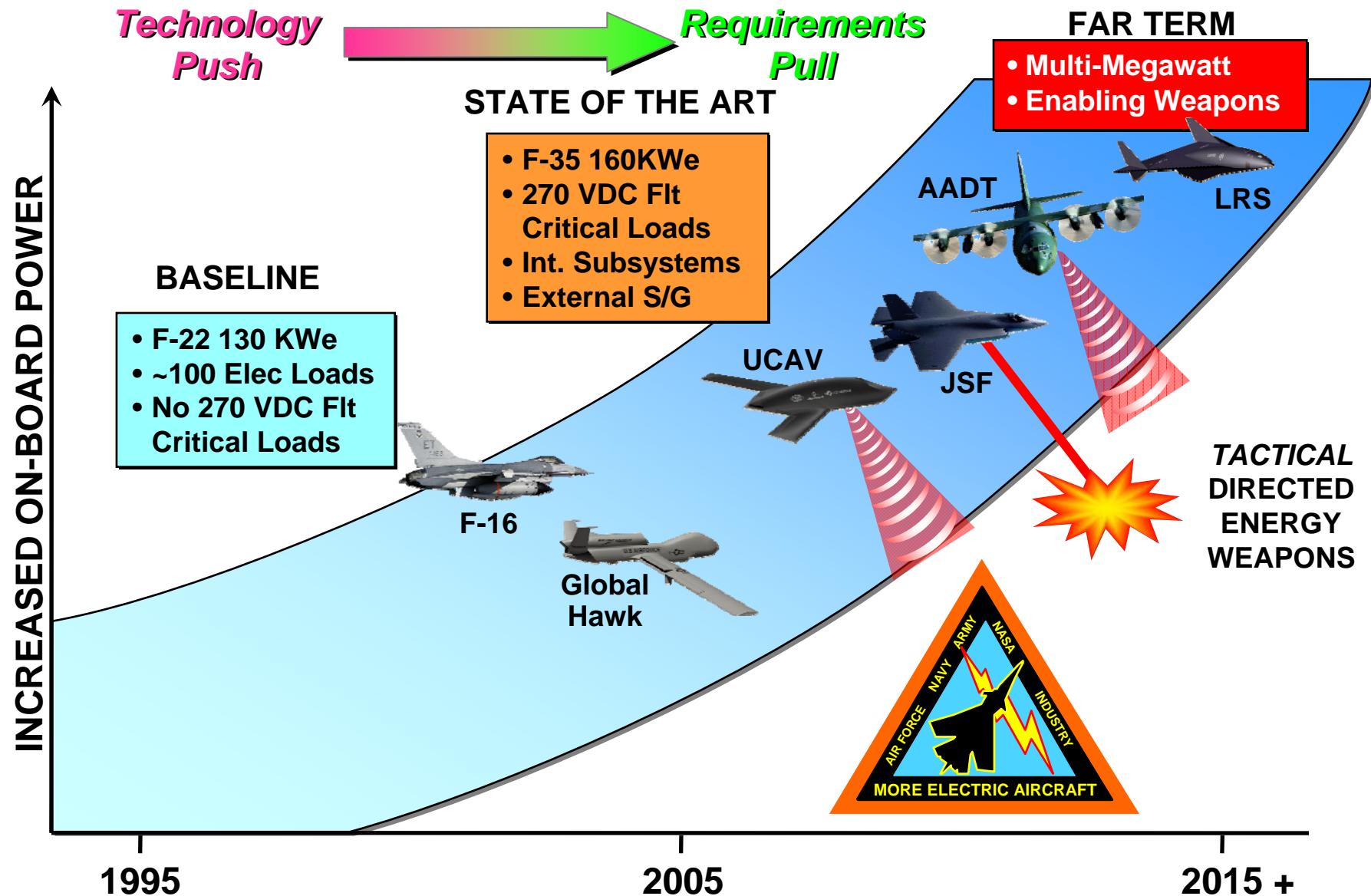


Exponential Growth for Power and Thermal Technology



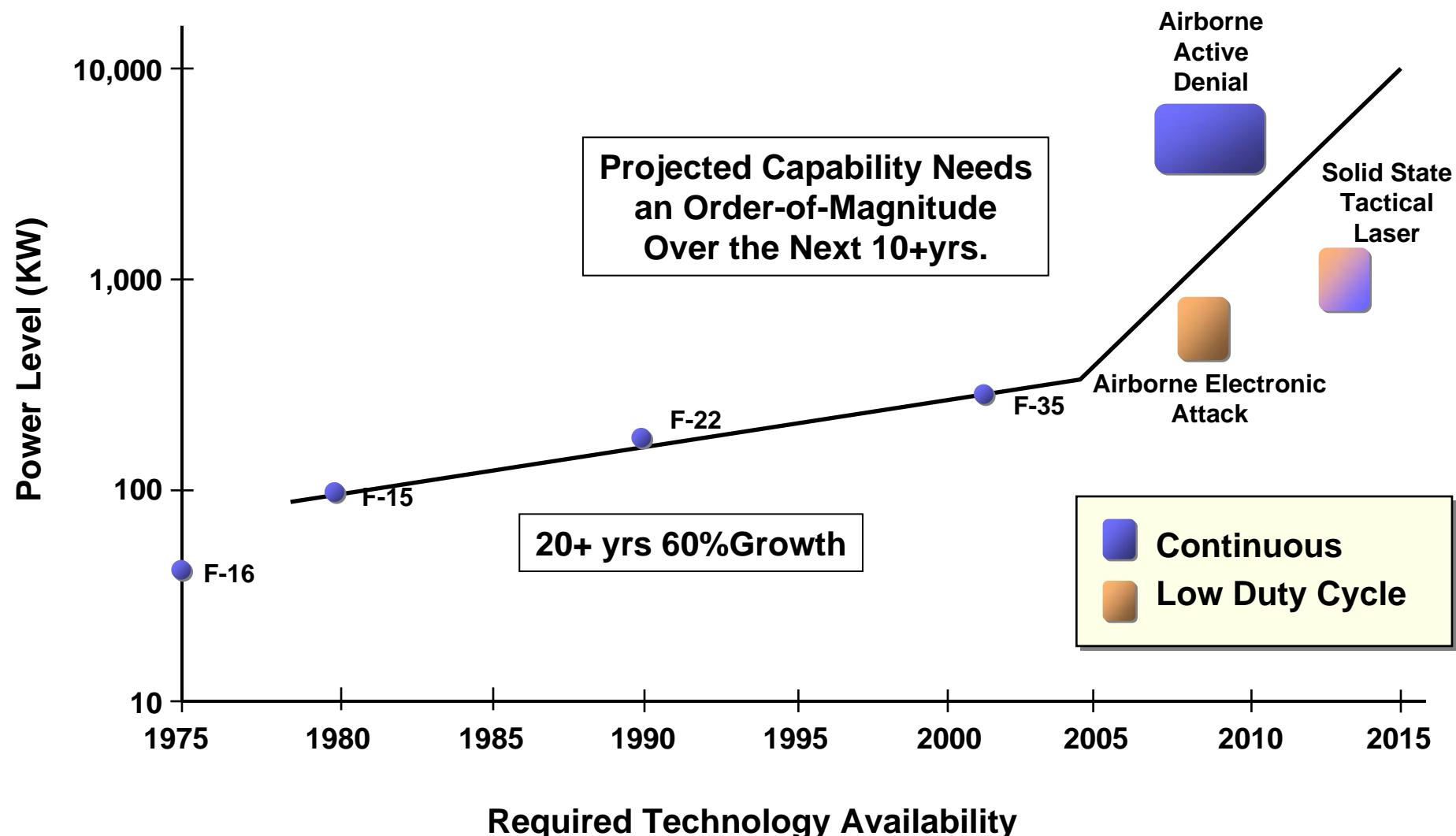


Exponential Growth for Power and Thermal Technology





DE Weapons Need Unprecedented Power & Thermal Management





HiPAC Technical Program Areas



Micro-Mini
Platforms

Munitions /
UAV

Tactical
Aircraft

Large
Platforms

Directed
Energy

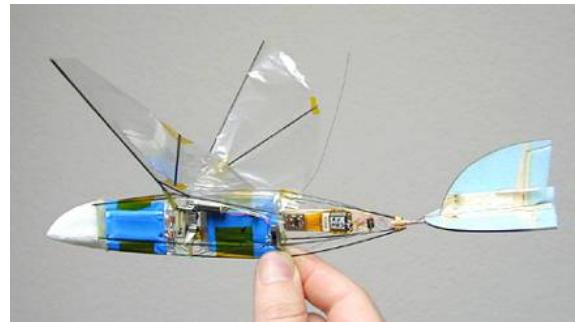
- **High Temperature Power System Components**
- **High Temperature Thermal Control Systems**
- **EMI Immunity**
- **Integrated Engine / Power Extraction**
- **Smart Power: Prognostics & Health Management**
- **MW Power Generation**
- **MMW Power Generation**
- **Active High Flux Thermal Control System**
- **Lightweight Compact Power Conditioning**
- **Energy Storage**
- **Electrochemical Power Generation**
- **MEMS Power Generation**
- **MEMS Thermal Management**
- **Pulse Power Components**
- **Subsystem Integration**



CAPABILITY FOCUSED

Micro-Mini Platforms

Small Platforms with sub kW
Power Requirements



Technologies:

- MEMS Power Generation
- MEMS Thermal Management
- Batteries
- Fuel Cells



TECHNOLOGY ENABLED

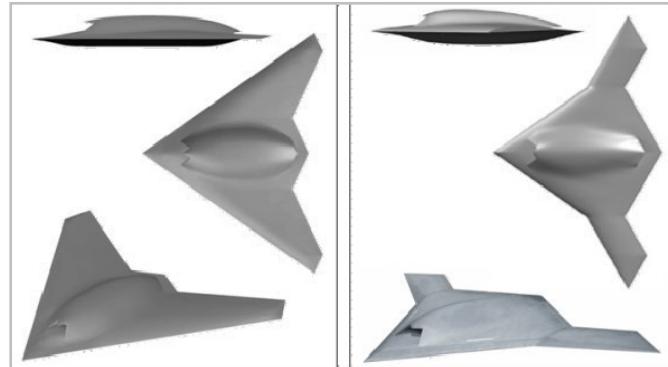


Munitions / Small UAVs



CAPABILITY FOCUSED

Munitions / Small UAVs with
1-100 kW Power Requirements



Technologies:



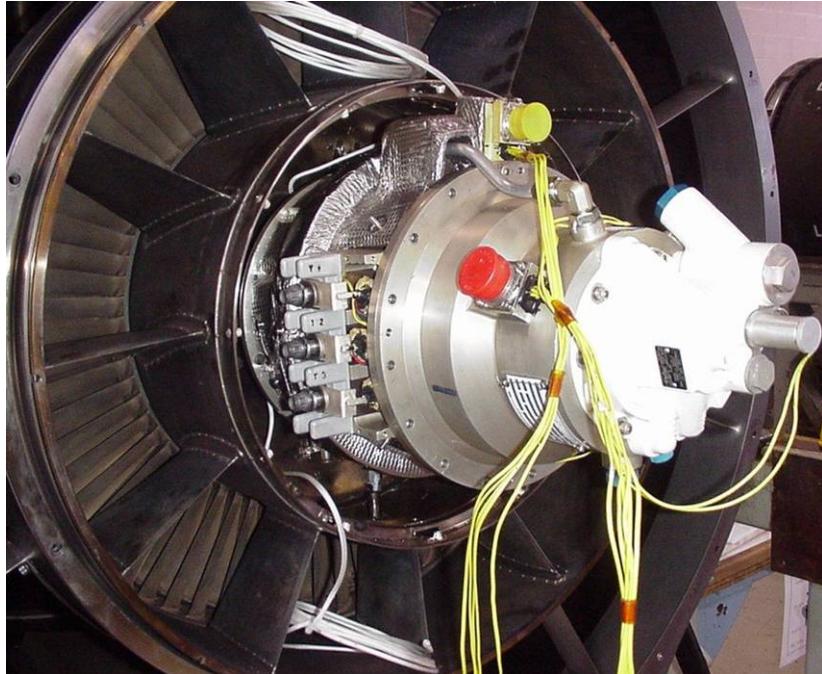
- EMI Immunity
- Integrated Engine / Power Extraction
- Smart Power – Prognostics and Health Management
- Electrochemical Power Generation
- Light Compact Power Conditioning
- Energy Storage



TECHNOLOGY ENABLED



Low Spool Generator for Global Hawk



Enables Advanced Sensor
Upgrades for Global Hawk

Power Technologies Benefits :

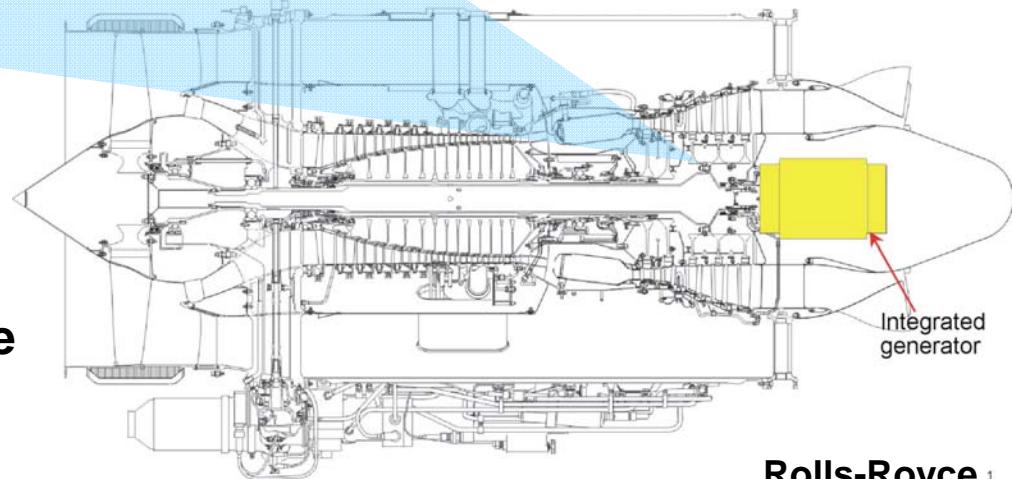
- 15% Thrust Improvement at Altitude
- 7.5X Increase in Power Generated

GLOBAL HAWK CAPABILITIES

NOW: 2000 lb Payload
24 Hour on Station
1200 NM range/ 60K ft altitude
10 KVA Payload Power

FUTURE: 3000lb Payload
20 Hour on Station
1200 NM range/ 60K ft altitude hold
25 KVA(Near-term); 75 KVA(Far-term)

AE3007 ENGINE - GLOBAL HAWK PROPULSION





Tactical Aircraft

CAPABILITY FOCUSED

Tactical Aircraft with 100-500 kW Power Requirements



Technologies:

- High Temperature Power System Components
- High Temperature Thermal Control Systems
- Energy Storage
- Integrated Engine / Power Extraction
- EMI Immunity
- Smart Power: Prognostics & Health Management
- Lightweight Compact Power Conditioning
- Electrochemical Power Generation



TECHNOLOGY ENABLED



Li Ion Battery



- B-2 Batteries >350 Flight Test Hours Logged
- Mars Rover Batteries Fully Operational After 7 Month Cruise Through Space

- Lithium Ion Technology Developed Under Joint AFRL/NASA/JPL Program Transitioned to B-2, F-35, and Mars Rovers



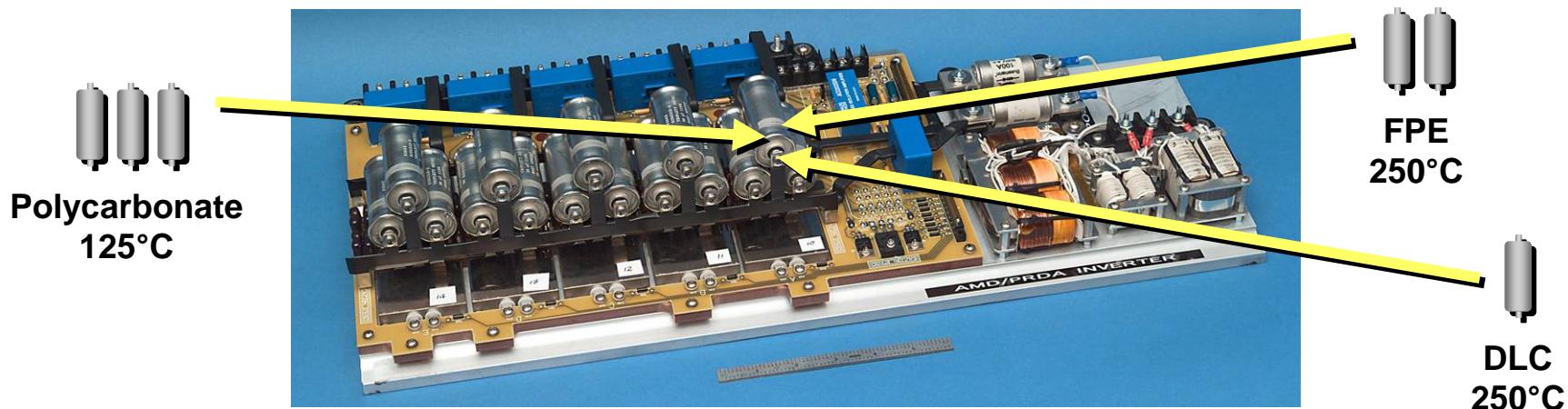
Revolutionary Capacitor Development



DIELECTRIC	DIELECTRIC CONSTANT	FILM THICKNESS	BREAKDOWN STRENGTH	UPPER-LIMIT TEMPERATURE	ENERGY DENSITY
POLYCARBONATE	3.2	3 m	5 KV/mil	125°C	> 1.0 J/g
FLUORENE POLYESTER (FPE)	3.4	3 m	10 KV/mil	250°C	> 2.0 J/g
DIAMOND-LIKE CARBON (DLC)	3.5	0.5 m	25 KV/mil	250°C	> 4.0 J/g

- Low cost DLC thin film in-house process scale-up (Mar 01); Commercialization by FY04 (energy density)

- Enables DEW -- 2X increase in energy density
- Reduces size, weight & volume





CAPABILITY FOCUSED

Large Platforms

Large Platforms with
250 kW - 2+ MW Power
Requirements



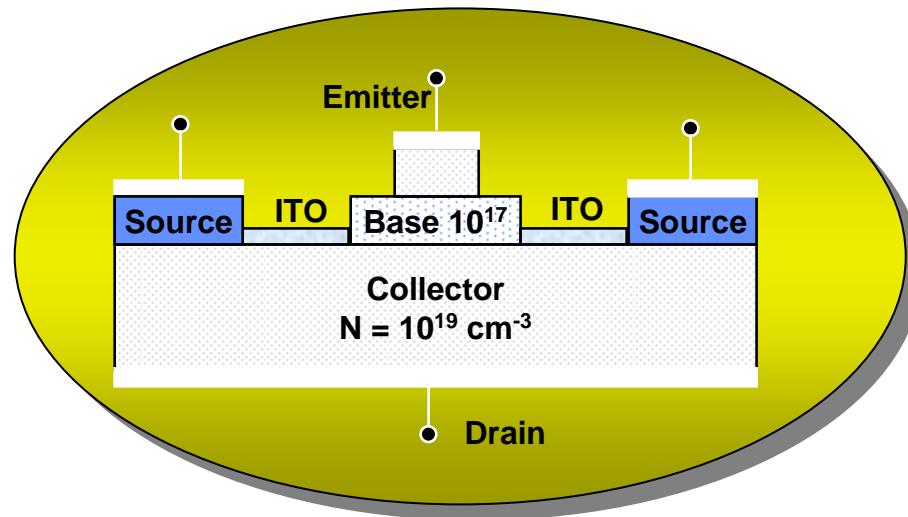
Technologies:

- MW-MMW Power Generation
- Integrated Engine / Power Extraction
- High Temperature Power System Components
- High Temperature Thermal Control Systems
- EMI Immunity
- Smart Power: Prognostics & Health Management
- Lightweight Compact Power Conditioning
- Energy Storage
- Electrochemical Power Generation

TECHNOLOGY ENABLED



Optically Triggered SiC Switch



TECHNICAL CHALLENGES:

Device design is foundational.
Carrier transport and optical
generation not quantified.

APPROACH:

- Develop key fabrication components
 - SiC photo-transistors (600V, 60-150A)
 - SiC “PGBT”-based switches
 - 2-D modeling in parallel with fab.
- Demo devices in electric actuator
drive controllers or I-H motor drive

OBJECTIVE & PAYOFF:

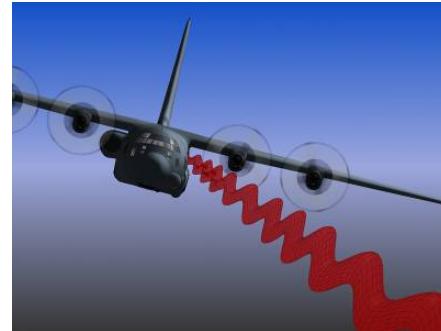
Reduce actuator weight while providing photonic switching device to satisfy the robust
actuator switching requirements for an EMI invulnerable FBL/PBW airframe concept.



Directed Energy

CAPABILITY FOCUSED

Directed Energy Concepts with 250 kW - MMW Power Requirements



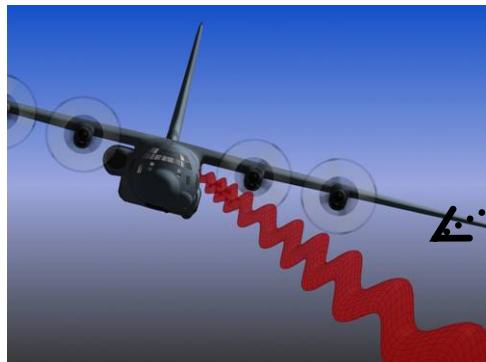
Technologies:

- Integrated Engine / Power Extraction
- MW-MMW Power Generation
- Active High Flux Thermal Control System
- Lightweight Compact Power Conditioning
- Energy Storage
- Pulse Power Components
- EMI Immunity
- High Temp. Power System Comp.
- High Temperature Thermal Control Systems
- Smart Power: Prognostics & Health Management

TECHNOLOGY ENABLED

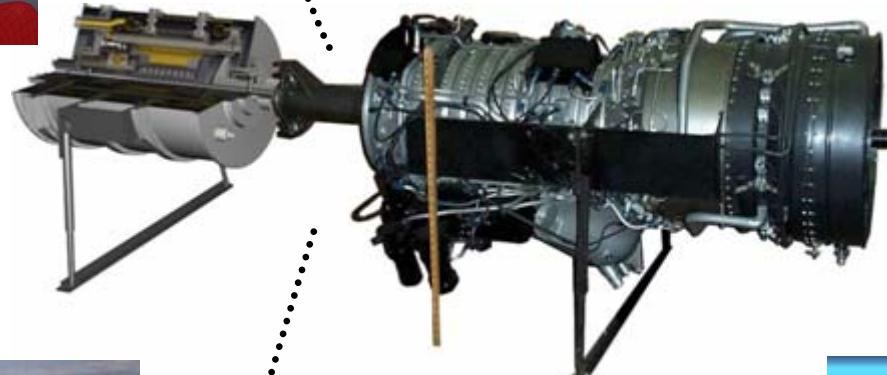


Multimegawatt Electric Power System



Directed Energy Weapons

1-5 MW Capability Needed for Multiple Applications

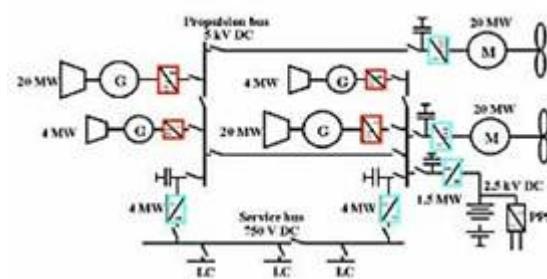


Navy Distributed Power



E-10A

Army Future Combat Systems Electric Weapons

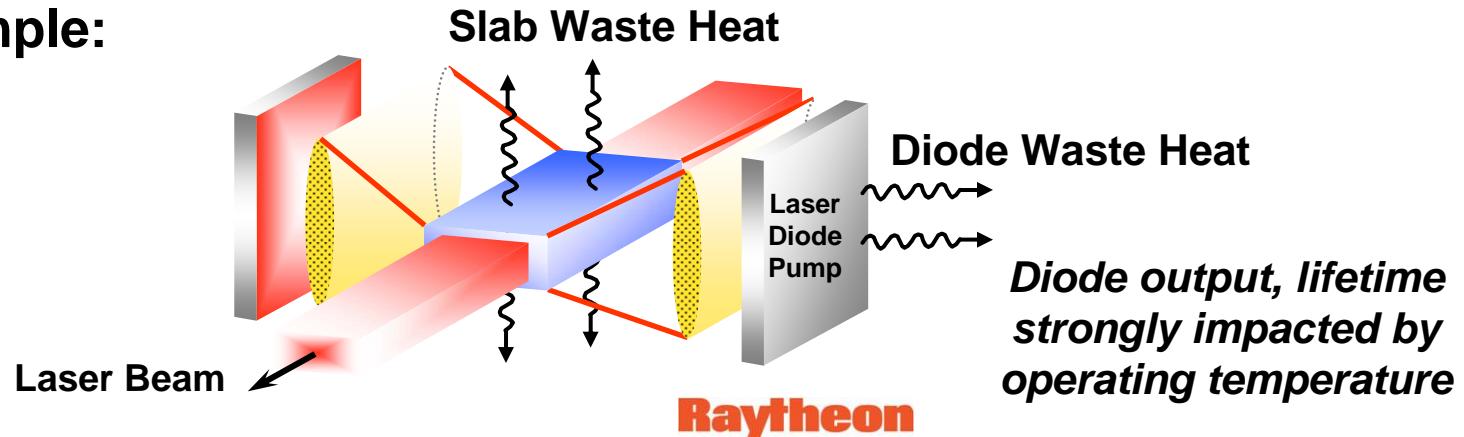




Power & Thermal Management ... Critical to DEW System Success

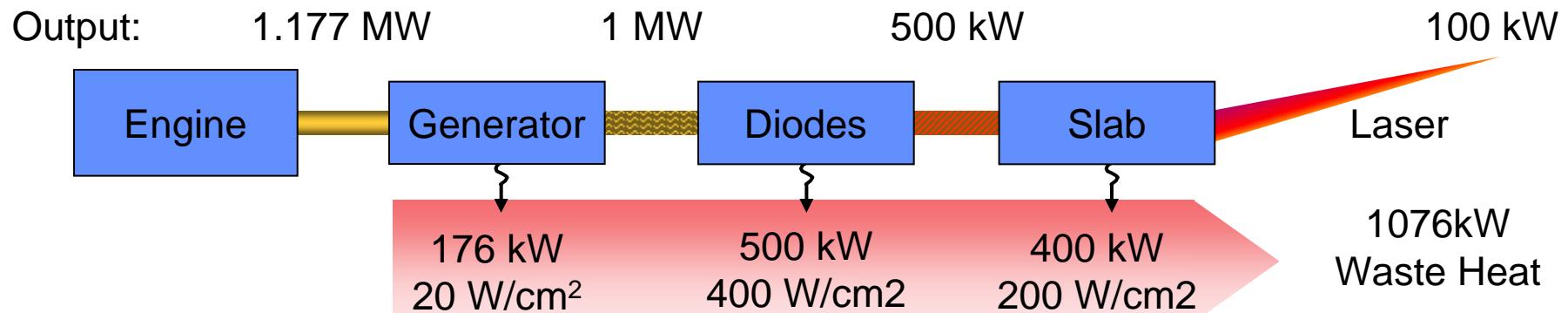


HEL Example:



The overall efficiency of solid state lasers vary from 10% to 30%, thus large amounts of waste heat must be managed

- As an example, for a 10% efficient laser





High Power for Aircraft Initiative



*Meet Today's
and Tomorrow's
Need for
Unprecedented
Power and
Thermal
Management*

*Five Power Regimes from
Watts to Multi-Megawatts*



*System
Approach to
Integrated and
Optimized
Weapons Power
and Thermal
Management*

Powering the United States Air Force!